ISACM Clinical MEG Primer
Categorical Course - FUNCTIONAL MAPPING

Mapping and Decoding Brain Function

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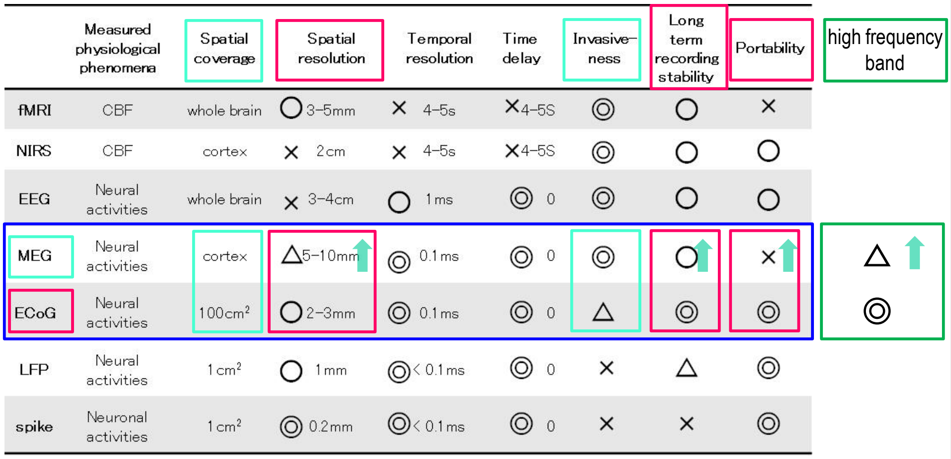
Brain signals used for mapping and decoding



	Measured physiological phenomena	Spatial coverage	Spatial resolution	Temporal resolution	Time delay	Invasive-ness	Long term recording stability	Portability	high frequency band
fMRI	CBF	whole brain	○ 3-5mm	× 4-5s	×4-5S	◎	○	×	
NIRS	CBF	cortex	× 2cm	× 4-5s	×4-5S	◎	○	○	
EEG	Neural activities	whole brain	× 3-4cm	○ 1ms	◎ 0	◎	○	○	
MEG	Neural activities	cortex	△5-10mm ↑	◎ 0.1ms	◎ 0	◎	○↑	×↑	△ ↑
ECoG	Neural activities	100cm^2	○ 2-3mm	◎ 0.1ms	◎ 0	△	◎	◎	◎
LFP	Neural activities	1cm^2	○ 1mm	◎< 0.1ms	◎ 0	×	△	◎	
spike	Neuronal activities	1cm^2	◎ 0.2mm	◎< 0.1ms	◎ 0	×	×	◎	

(Hirata et al, Chapter 5 in Clinical System Neuroscience, 2015)

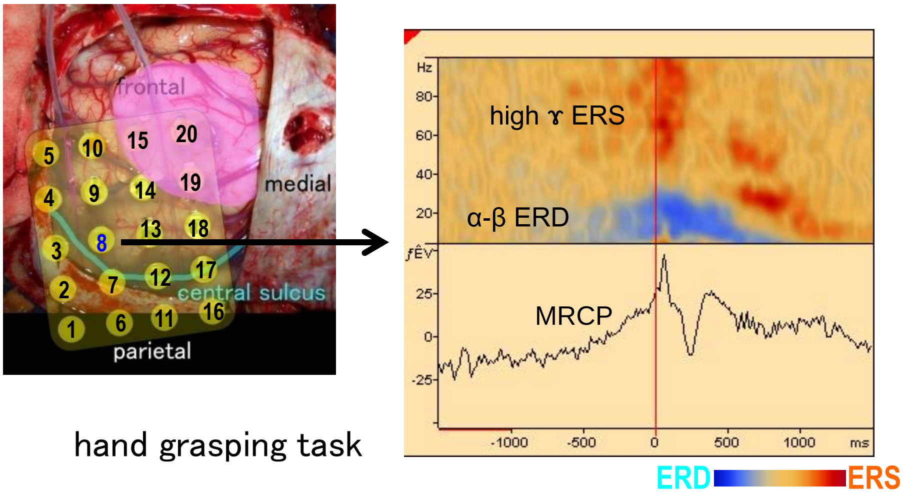
Contents

- Mapping sensorimotor function
- Mapping language function
- Neuromagnetic tracking of subcortical fibers
- Decoding motor function

Mapping sensorimotor function

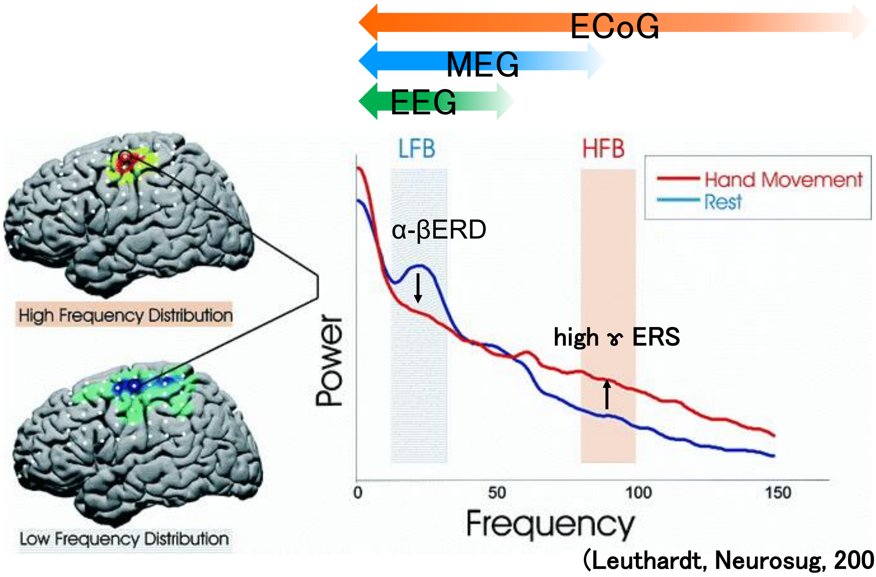
Cerebral oscillatory changes

Power increase: event-related desynchronization (ERD)
Power decrease: event-related synchronization (ERS)



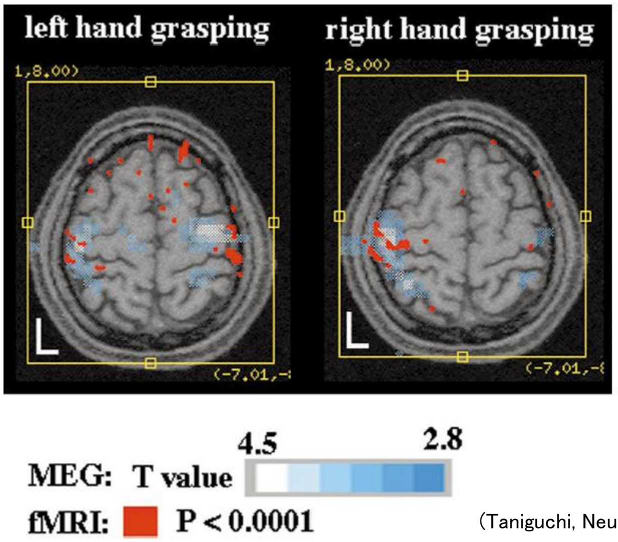
hand grasping task

High frequency oscillation well reflects functional localization.



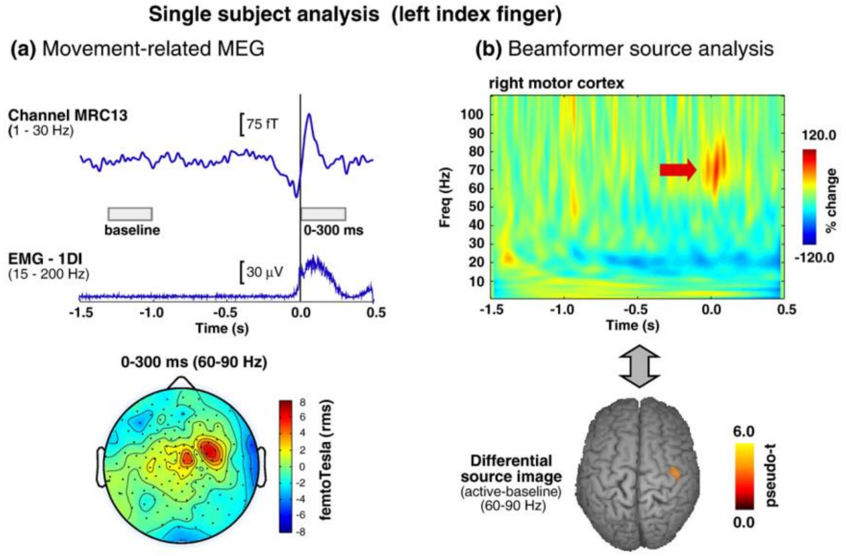
(Leuthardt, Neurosug, 2006)

Movement-related β ERD is consistently detectable.



（Taniguchi, Neuroimage, 2000）

Movement-related high ɣ ERS may be detected.

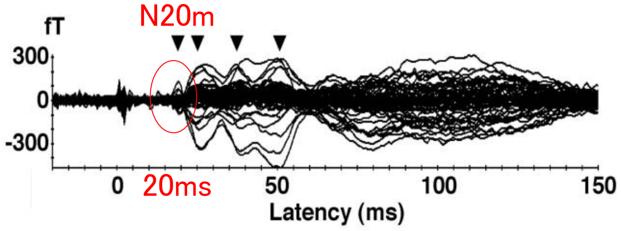


(Cheyne D, et al, Neuroimage, 2008)

Somatosensory function

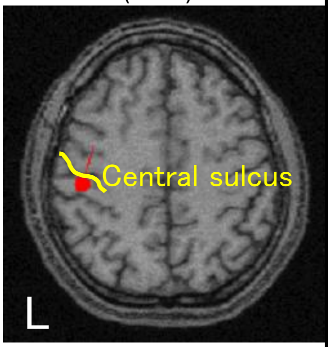
Somatosensory evoked magnetic field (SEF)

Average waveforms



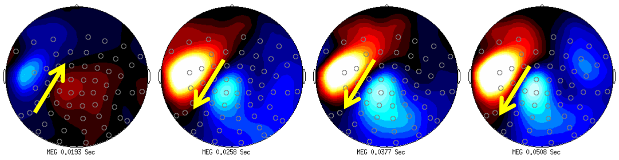
Identification of the central sulcus

Equivalent current dipole (ECD)



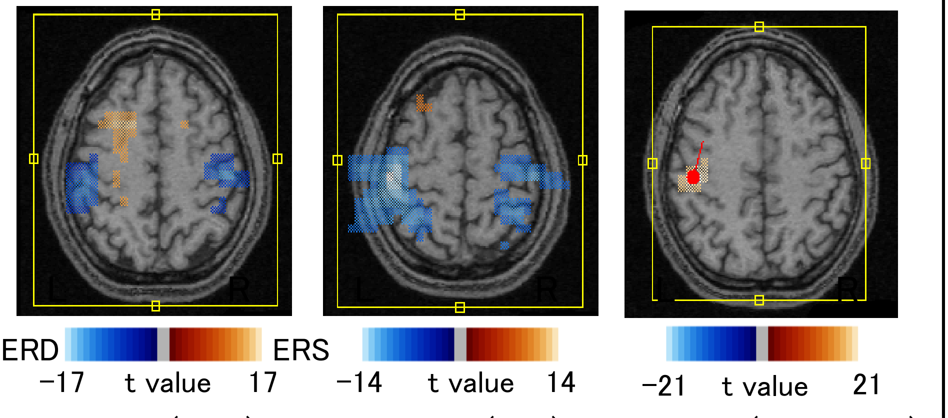
error 3.2%

Magnetic fields



N20m Dipole, $\alpha-\beta$ ERD, high γ ERS are consistently detectable.

Rt median nerve electrical stimulation



8–13Hz (alpha)

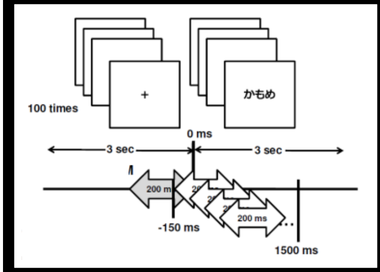
13–25Hz (beta)

50–200Hz (high gamma)
10–600ms

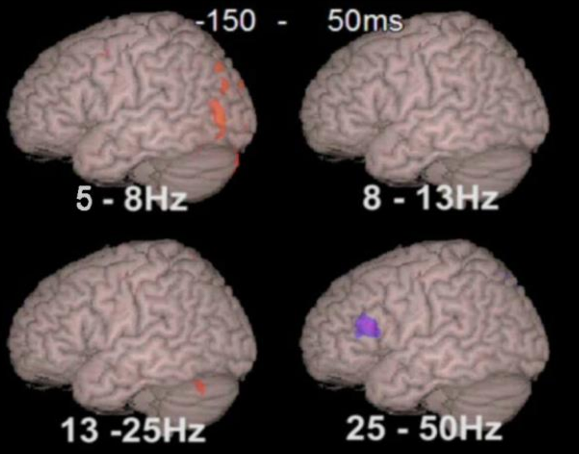
(Hirata, Neurosci Let, 2002)

Mapping language function

Temporal profiles of oscillatory changes related to silent reading

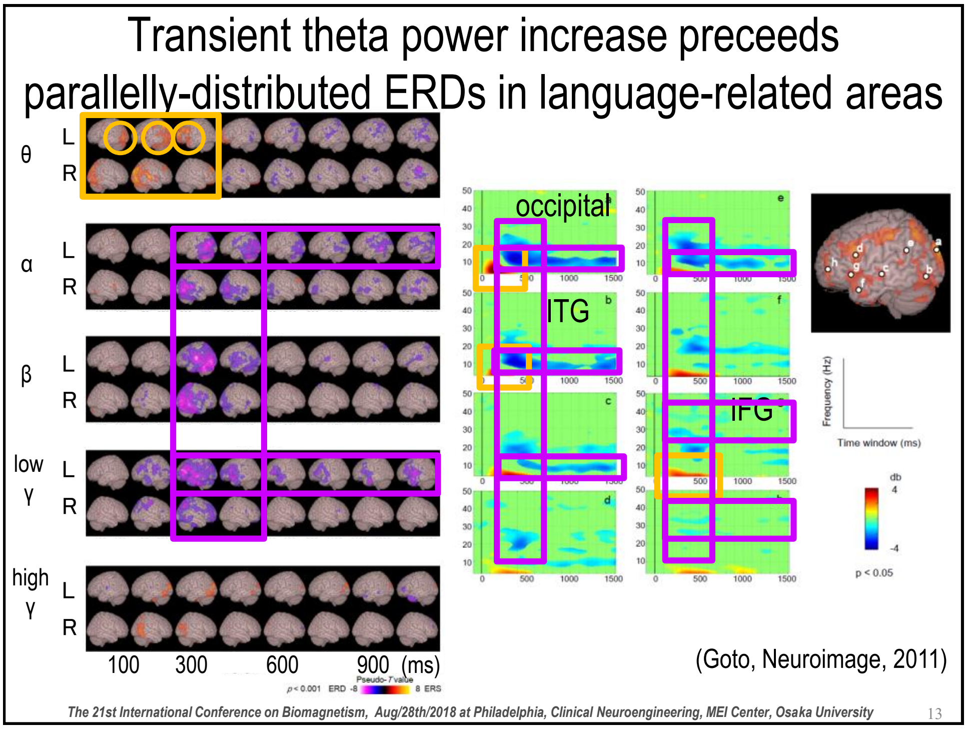


Sliding time window analysis



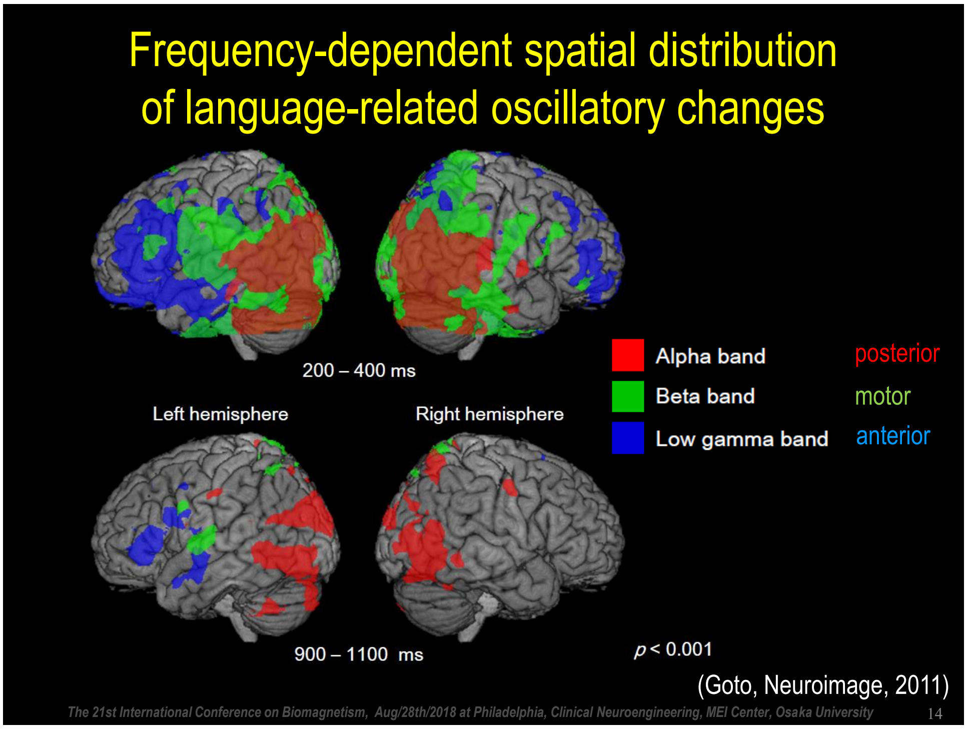
ERS ▨ **ERD**

(Goto, Neuroimage, 2011)



Transient theta power increase preceeds parallelly-distributed ERDs in language-related areas

(Goto, Neuroimage, 2011)



Frequency-dependent spatial distribution of language-related oscillatory changes

🟥 Alpha band posterior

🟩 Beta band motor

🟦 Low gamma band anterior

$p < 0.001$

(Goto, Neuroimage, 2011)

Comparison with the Wada test

Detection rate of frontal ERD: 95.9%

(Hirata, J Neurosurg, 2010)

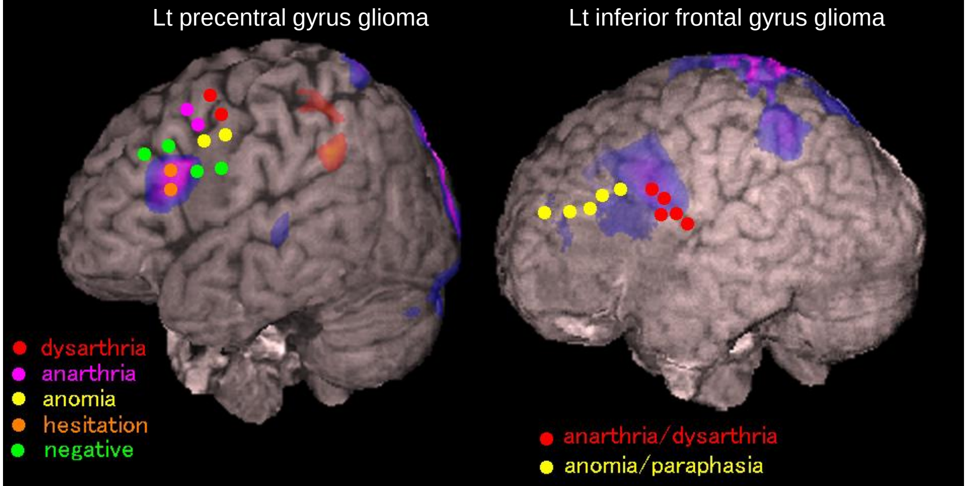
Total 77 cases: consistency 86.5%, sensitivity 89.2%, specificity 95.9%

	Wada test			
SAM	left	bileteral	right	inconclusive
left	56	3	0	1
bileteral	1	3	1	0
right	1	1	5	2
inconclusive	3	0	0	0

Left-handed or ambidextrous 13 cases:
consistency 76.8%, sensitivity 84.6%, specificity 92.3%

	Wada test			
SAM	left	bilateral	right	inconclusive
left	5	0	0	0
bilateral	0	1	1	0
right	0	0	4	0
inconclusive	2	0	0	0

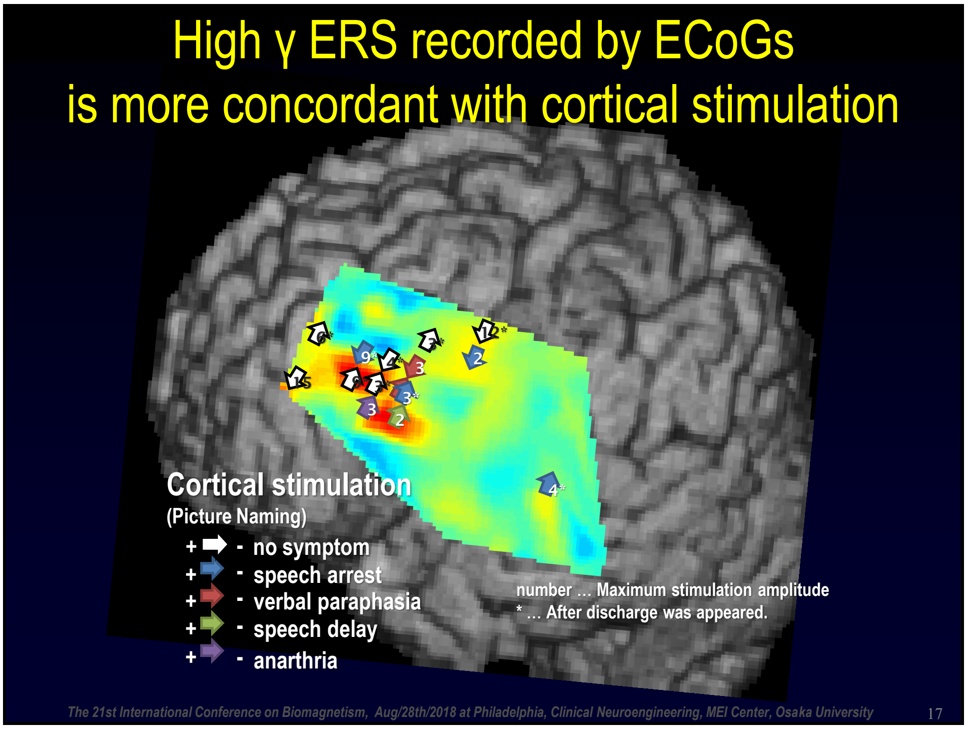
Comparison with cortical stimulation



Deviation : 6.0±7.1mm / 17cases

ERS ▬ ERD

(Hirata, J Neurosurg, 2010)

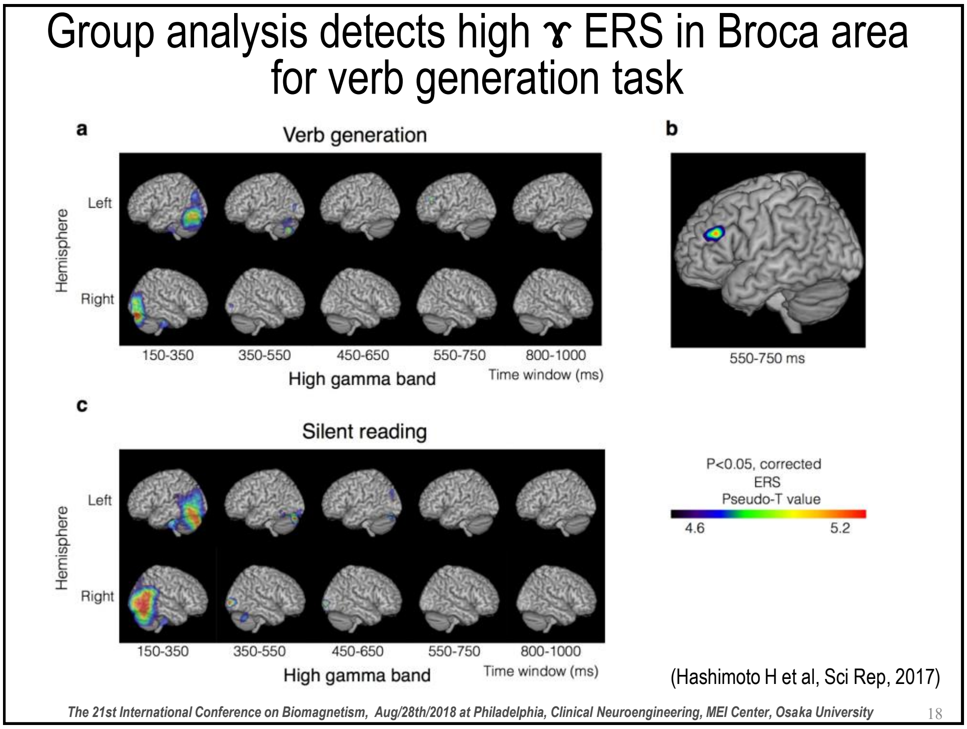


High γ ERS recorded by ECoGs is more concordant with cortical stimulation

Cortical stimulation
(Picture Naming)

- + ➡ - no symptom
- + ➡ - speech arrest
- + ➡ - verbal paraphasia
- + ➡ - speech delay
- + ➡ - anarthria

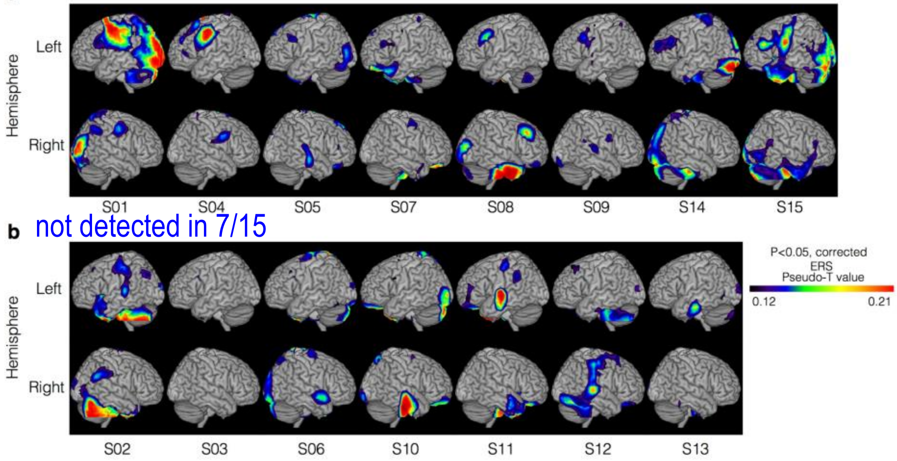
number … Maximum stimulation amplitude
* … After discharge was appeared.



Group analysis detects high ɤ ERS in Broca area for verb generation task

(Hashimoto H et al, Sci Rep, 2017)

Language-related high ϒ ERS was detected in 8/15



detected in 8/15

not detected in 7/15

(Hashimoto H et al, Sci Rep, 2017)

Summary

Cortical mapping

- Somatosensory

  Dipole and high ϒ ERS are reliable.
- Motor

  Dipole and β ERD are reliable.

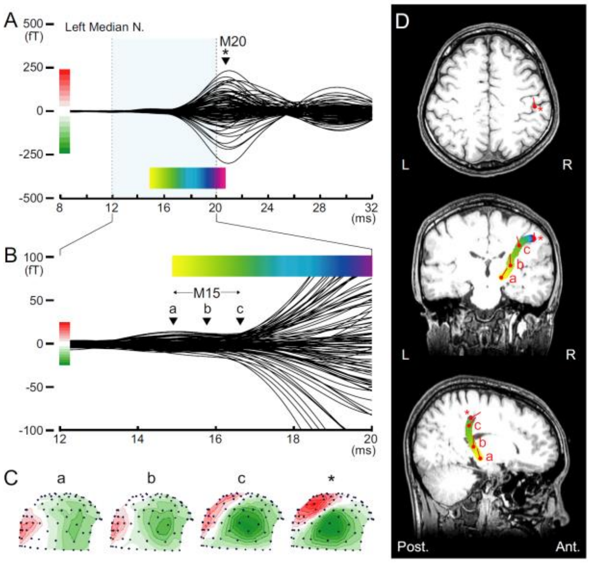
  High ϒ ERS may be useful if detected
- Language

  Frontal low ϒ ERD is reliable.

  High ϒ ERS is still challenging.

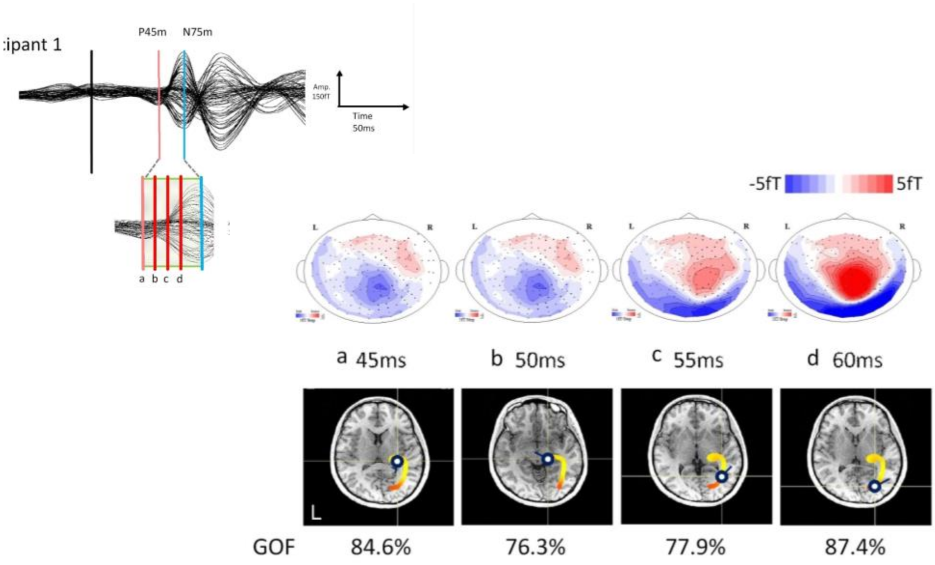
Neuromagnetic tracking
# of subcortical fibers
: still challenging

Thalamo-cortical fiber

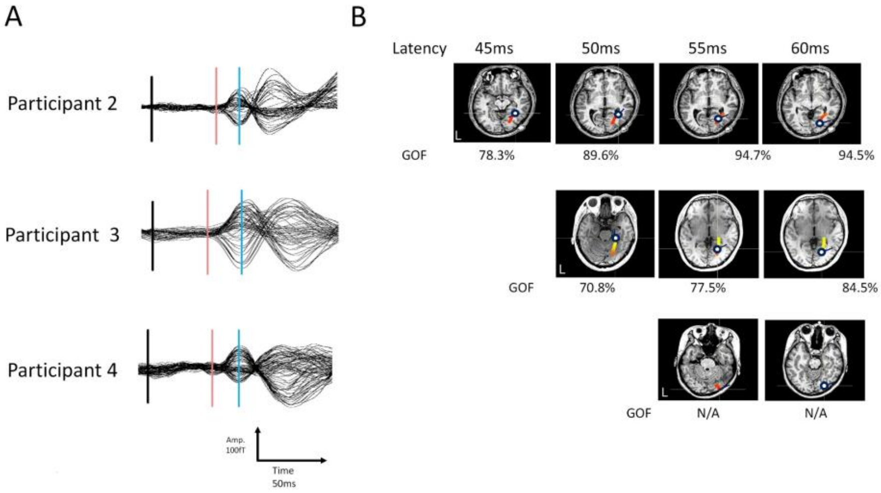


(Kimura T ett al, J Neurosci, 2008)

Subcortical visual pathway



(Yoshida et al, Sci Rep, 2017)

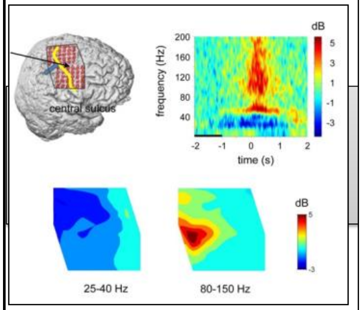


(Yoshida et al, Sci Rep, 2017)

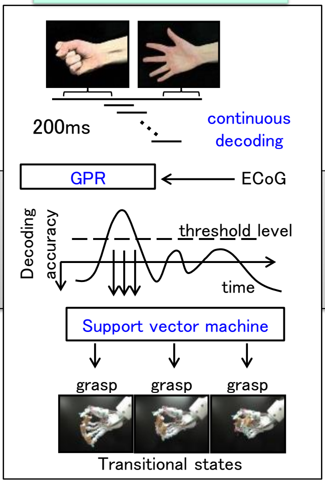
Decoding motor function

ECoG-based human BMI system

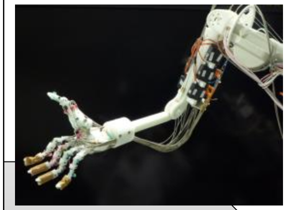
ECoG recording

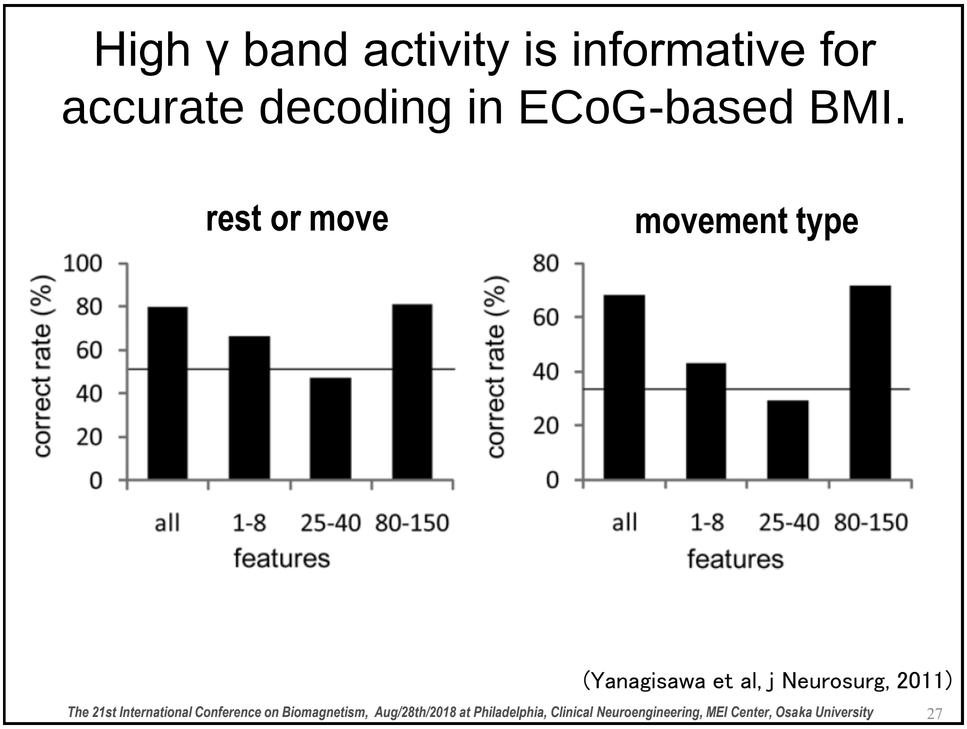


Neural decoding: SVM + GPR



Robotic hand control





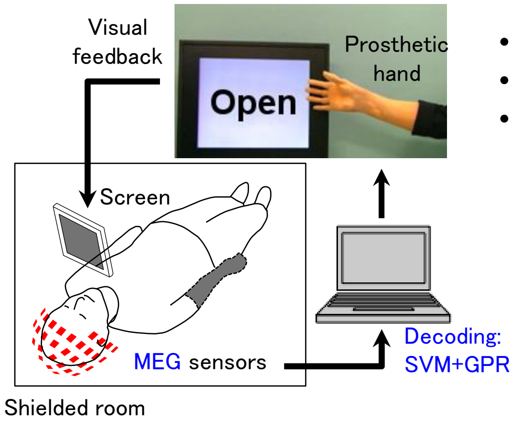
High γ band activity is informative for accurate decoding in ECoG-based BMI.

（Yanagisawa et al, j Neurosurg, 2011）

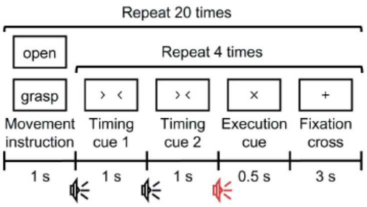
Real time robotic control by ECoG measurements

（Yanagisawa et al, j Neurosurg, 2011）

MEG-based BMI for hand control

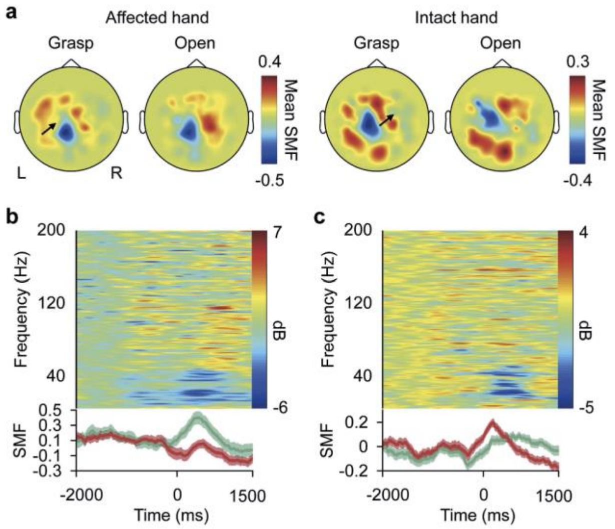


- 6 healthy and 9 paralyzed
- Grasp and open: 2 types
- 40 trials for each movement type



（Fukuma et al, PlosOne, 2015; Fukuma et al, Sci Rep, 2016）

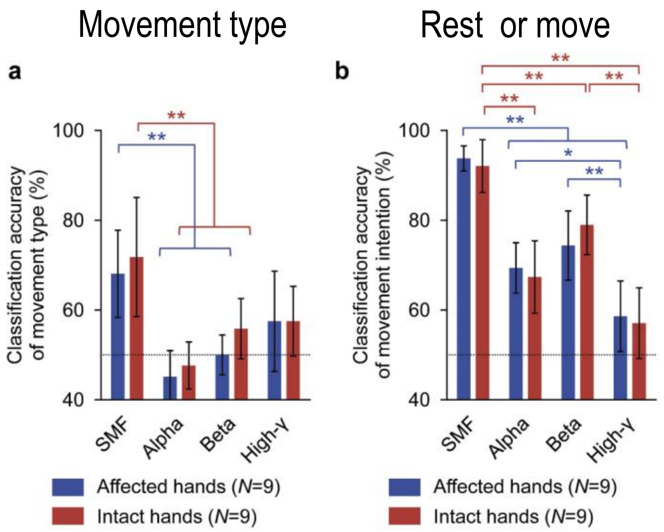
Magnetic fields and spectral maps during hand movements : no clear activity in the high γ band (Patient 1 with cervical cord avulsion)



SMF(Slow Magnetic Fields):
Smoothed MRCF

（Fukuma et al, Sci Rep, 2016）

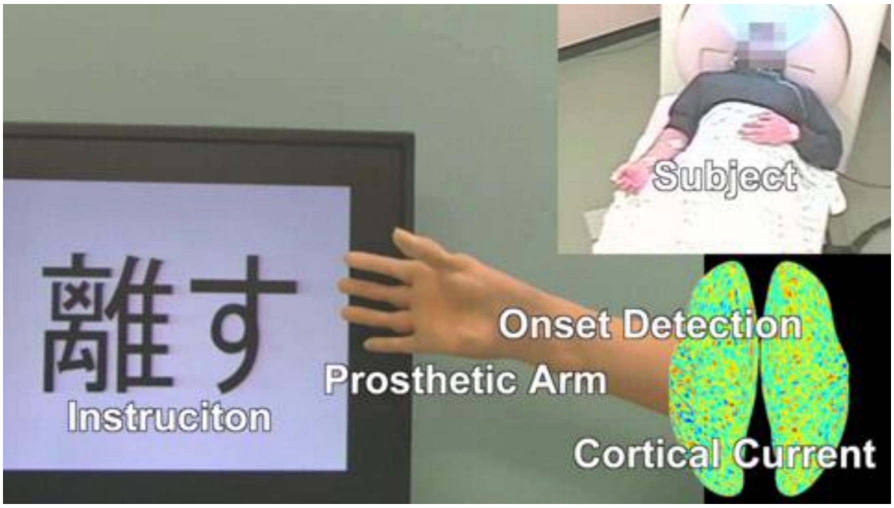
Decoding accuracy by MEG measurements


Movement type

Rest or move

(Fukuma et al, Sci Rep, 2016)

Real time robotic control by MEG measurements



(Fukuma et al, Sci Rep, 2016)

Summary

- High sensitivity of ECoG in the high frequency band enables ECoG-based BMI accurate decoding.
- Sensitivity of MEG in the high frequency band is inferior to that of ECoG

Powers of magnetic fields offer higher decoding accuracy than high gamma activity.

Issues

- Sensitivity in the high frequency band
- Detection of subcortical activity